TITLE OF INVENTION

Minimal Resistance Scallop for a Well Perforating Device

CROSS-REFERENCE TO RELATED APPLICATIONS

Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

REFERENCE TO A MICROFICHE APPENDIX

Not Applicable

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to an improvement in the design of an oil and gas well perforating device. The improvement applies to a type of perforating device that is typically lowered into the well through the casing or tubing in the well to a position where the explosive charges are detonated at the desired depth. The improvement is a method of modifying the scallop that is cut on the exterior of the device, at the location of a perforating charge, so as to minimize the resistance to the explosive charge which in turn improves the performance of the perforating charge by increasing its depth of penetration and hole size.

[0002] After an oil or gas well is drilled, steel casing is lowered into the well and cemented to the adjoining rock formations. Typically, perforations are needed to allow the oil or gas from the desired rock formation to be able to flow into the casing and then out of the well. The perforations are made by lowering, on a wireline or tubing, the perforating gun containing

explosive charges to the desired depth and detonating the charges. There are several different types of perforating guns.

[0003] One type of perforating gun is referred to as a casing gun. A casing gun is a hollow steel carrier that is lowered into the casing of the well with the perforations made through screwed in ports. These screwed in ports are used to allow the ports to be removed and the perforating gun used again. Since the present invention relates to an improvement in a scallop for the perforation, the present invention is not applicable to a casing gun.

[0004] A second type of perforating gun is an expendable casing gun. This is similar to the previously discussed casing gun with the addition of larger charges that will cause significant distortion to the hollow steel carrier. The distortion is sufficient to make the hollow steel carrier useable only one time and therefore expendable. The larger charges are sometimes needed when greater penetration is required such as when some of the rock formation has washed away and there is a greater amount of cement to penetrate. An expendable casing gun will have scallops cut for the perforations or may have no scallops at all which is referred to as run slick.

[0005] A third type of perforating gun is a tubing conveyed perforating gun. The tubing is a retrievable string of pipe inside of the casing that is permanently cemented in place. This is another type of casing gun except the carrier is made a part of the tubing string rather than being run on the wireline. The carrier can have scallops or be slick.

[0006] All of the previously discussed perforating guns are made to be lowered into the casing. There are also perforating guns made to be lowered into the tubing. These through tubing perforating guns are designed to be utilized while leaving the tubing inside the well and casing. In order for the perforating guns to be lowered inside of the tubing requires a smaller

diameter perforating gun. The through tubing perforating guns are lowered through the tubing to a desired depth, below the bottom of the tubing, at the desired rock formation.

[0007] A fourth type of perforating gun is a through tubing strip gun run on wireline. This type of perforating gun includes a strip carrier on which capsule shaped charges may be mounted. The capsule shaped charges are sealed to protect the charges from the well environment. At detonation the strip gun is basically blown apart and the debris drops to the bottom of the well below the perforations. Any intact portion of the strip gun is then retrieved through the tubing. There is no hollow steel carrier needed for the through tubing strip gun and so the present invention is not applicable to this type of perforating gun.

[0008] A fifth type of perforating gun is the retrievable through tubing gun which is like the casing gun in that it uses a sealed carrier to hold the charges but is a smaller diameter to fit inside the tubing. These smaller diameter carriers utilize the scallops and the present invention would be applicable.

[0009] In summary, the present invention is applicable to all of the types of perforating guns with the exception of the casing gun that uses screwed in ports and the strip gun that has no carrier. All of the perforating guns discussed utilize a sealed carrier with the exception of the strip gun. The sealed carriers usually have recessed areas or scallops at the location of the charges. The recessed area was originally made to compensate for the burr formed on the outside of the carrier and also serves to reduce the amount of energy the charge loses in exiting the perforating gun. The recessed area of reduced wall thickness can be accomplished in different ways, such as removable plugs for the casing gun, but the most common method is to make a cut into the outer surface of the perforating gun at the location of each perforating charge.

This type of cut is typically referred to as a scallop. Removing more steel in the scallop is limited by the decrease in strength of the carrier.

[0010] There are no known attempts to modify the scallop, cut in the carrier, in order to further reduce the thickness of the steel by changing the geometrical shape of the scallop to make it structurally stronger. Schlumberger has two patents related to shaped geometry recesses to reduce or control reflection of compression waves generated from the explosive jet. Schlumberger has a method of making the recess by drilling a round hole perpendicular to the carrier with a resulting flat bottom and a ninety degree angle between the flat bottom and side. This is the prior art as described and drawn by Schlumberger. Schlumberger then offers in patent 6,460,463 B1 and 6,523,474 B2 a variety of different geometrical shapes, usually with sloping sides, that could reduce the compression waves generated by use of Schlumberger's prior art. The prior art and improvements described in that patent are unique to the way that Schlumberger makes their recesses.

[0011] The normal method utilized in the industry is the scallop which removes more steel over a larger area. The compression waves are not considered of any consequence in such a design as there is little to no sides to constrict the compression waves. The industry standard scallop method does not require as much accuracy in aiming the perforating charges as the Schlumberger method. The present invention adds a geometric cut to the scallop to remove more steel while increasing the mechanical strength of the carrier to withstand the internal and external pressures.

[0012] There continues to be a need to be able to minimize the energy lost by the perforating jet in exiting the sealed hollow steel carrier of the perforating guns. Any reduction in the energy lost exiting the carrier is available to the perforating jet to be able to penetrate deeper

into the rock formation. Increasing the depth of penetration and hole size are the most important factors in the performance of a perforating gun. The method of reducing the lost energy must also maintain sufficient integrity of the carrier housing.

SUMMARY OF THE INVENTION

[0013] The present invention is an improvement for a well perforating device and method of manufacture to make a modification to the industry standard method of cutting a scallop on the outer surface of the hollow steel carrier that contains the perforating charges. The scallops are made at the location of each charge to reduce the energy needed to exit the carrier. The present invention is the use of an arching geometric cut for the scallop. The thickness of the carrier at the location of the scallop can be reduced while maintaining sufficient structural strength to withstand the pressures exerted on the carrier, as a result of the additional strength imparted from the arched geometric cut. The deeper arching geometric shape reduces the thickness of steel that the perforating jet must penetrate to exit the carrier which increases the remaining energy for greater penetration and hole size. Increasing the depth of cut of the scallop alone to the same thickness would result in significantly reduced structural strength of the carrier and failure to withstand the external pressures exerted on the carrier. The additional smaller geometric cut utilizes the additional strength created from the rigidity of the geometric cut to counter the effects of the reduced thickness.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a partial side view of the prior art elliptical scallop cut on the outside of the perforating device hollow steel carrier.

[0015] FIG. **2** is a partial, cross sectional view of the prior art elliptical scallop cut along the longitudinal axis of the device of FIG. **1** along line **2-2**.

[0016] FIG. **3** is a partial, cross sectional view of the prior art device of FIG. **2** along line **3-3**.

[0017] FIG. **4** is a partial side view of the first preferred embodiment of the present invention showing the resulting elliptical shape made by a round bottom cut on the outside of the perforating device hollow steel carrier.

[0018] FIG. **5** is a partial, cross sectional view of the first preferred embodiment of the present invention along the longitudinal axis of the device of FIG. **4** along line **5-5**.

[0019] FIG. **6** is a partial, cross sectional view of the first preferred embodiment of the present invention device of FIG. **5** along line **6-6**.

[0020] FIG. **7** is a partial side view of the second preferred embodiment of the present invention showing the resulting elliptical shape made from a round flat bottom cut on the outside of the well perforating device hollow steel carrier.

[0021] FIG. **8** is a partial, cross sectional view of the second preferred embodiment of the present invention device along the longitudinal axis of the device of FIG. **7** along the line **8-8**.

[0022] FIG. **9** is a partial, cross sectional view of the second preferred embodiment of the present invention device of FIG. **8** along line **9-9**.

[0023] FIG. **10** is a partial side view of the third preferred embodiment of the present invention showing the elliptical shape of a standard scallop with an additional longer and narrower geometric cut along the longitudinal axis on the outside of the well perforating device hollow steel carrier.

[0024] FIG. **11** is a partial, cross sectional view of the third preferred embodiment of the present invention device along the longitudinal axis of the device of FIG. **10** along the line **11-11**.

[0025] FIG. **12** is a partial, cross sectional view of the third preferred embodiment of the present invention device of FIG. **11** along line **12-12**.

DETAILED DESCRIPTION

[0026] In the following description, details of the present invention are given to provide an understanding of the present invention. However, those skilled in the art will know that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments are possible.

[0027] Recesses formed in the outer wall of a body member **10** are to enhance the performance of the shaped charge perforating jets or other explosives. The thinned area allows for less energy to exit the body member **10** and more energy to penetrate the rock formation. The preferred embodiments presented are shaped with geometric cuts to remove more steel, to improve performance, while utilizing the strength of the geometric cut to maximize the remaining strength of the body member **10** to withstand the hydrostatic pressures exerted by the wellbore fluids. One of the preferred embodiments is adding a geometric cut to the industry standard elliptical scallop **12**.

[0028] FIG. **1** is a side view of a typical industry standard prior art scallop **12** cut into the outside of the round tubular body member hollow steel carrier **10** as part of a typical prior art perforating device used to perforate the casing, cement and rock formation in an oil and gas well to allow the reservoir fluids to flow into the well. The perforating device comprises a cylindrical body member **10**, which is sealed to protect the plurality of perforating charges, not shown, from the fluids in the wellbore and from the hydrostatic pressures of those fluids. The body member **10** has a smaller outer diameter than the inner diameter of the casing or tubing in order for the body member **10** to be slidably received within the longitudinal inner diameter of the casing or

tubing. The body member **10** outer diameters range from one and three eighths inches to seven inches and are most typically in the two to four inch range.

[0029] There is a prior art scallop **12** cut in the outer wall of the body member **10** where the perforating charge is positioned. The prior art scallop **12** is aligned with the perforating charge such that the perforating jet exits through the prior art scallop **12** to lessen the force needed to exit the body member **10**. Decreasing the force needed to exit the body member **10** increases the remaining force available to penetrate deeper into the rock formation. When the perforating charges are detonated, the perforating jet should exit the body member **10** of the perforating gun at the center of the scallop **12** where the bottom flat section of the scallop has reduced the steel of the body member **10** to its minimum thickness. The minimum thickness of the steel allows for less of the energy from the perforating jet to be used to exit the body member **10** which allows more energy to be available to penetrate into the rock formation. The minimum thickness of the steel is balanced with the need to have sufficient thickness of steel to withstand the hydrostatic pressure exerted on the body member **10** along with providing for thickness variations in the original body member **10**.

[0030] The strength of the tubular hollow steel carrier body member **10** depends primarily upon the thickness and diameter of the carrier. The greater the thickness of the body member **10** provides additional strength. The smaller diameter of the body member **10** also serves to provide additional strength as the tighter arch of the tubular hollow steel carrier body makes the body member able to withstand greater forces. It is this same principle of the arch shape providing additional strength, that allows the present invention to remove more steel where the perforating jet exits the body member **10** while still maintaining sufficient structural integrity to resist the hydrostatic pressures. The additional strength created by the arching geometric cut

allows more steel to be removed which in turn allows for greater penetration into the rock formation. The structural dynamics of an arch distributes the load laterally along the curvature of the arch.

[0031] The concept of the present invention and the preferred embodiments all use a geometric cut with an arch. Using an arch in the geometric shape of the cut could allow for many variations. Testing of various shapes on various hollow steel carrier body members has resulted in three preferred embodiments. These three preferred embodiments are not the only possibilities applying the concept of the present invention.

[0032] The first embodiment of the present invention is depicted in a side view in FIG. **4** and in cross sections in FIG. **5** and FIG. **6**. This embodiment is a radius cut scallop **14**. The radius cut scallop **14** is comprised of one continuous curved surface **16**. The elliptical shape of the radius cut scallop **14** is a result of the longitudinal length of the scallop being longer with all of the scallop being a curved surface with no flat area. The embodiment uses the strength of the arch from the radius cut to allow for more steel to be removed with less steel remaining for the perforating jet to penetrate. The strength of the arch provides additional strength to resist the hydrostatic forces of the wellbore fluids. Using the same thickness of steel with a standard scallop would collapse under the hydrostatic forces.

[0033] There are no known attempts to accomplish the result of the present invention. There are however, two patents dealing with a similar shape as the first embodiment of the present invention. Schlumberger is a large manufacturer of perforating guns and has two patents dealing with various geometric shapes of recessed areas for perforations to reduce or control reflection of compression waves generated in response to the perforating jet. These patents, 6,460,463 B1 and 6,523,474 B2, provide for various shapes of recessed areas to reduce

compression waves resulting from the explosive charge. The embodiments of these Schlumberger patents are alterations to the standard Schlumberger recessed area, referred to as the prior art in those patents, which is simply a round flat bottom cut with ninety degree angle sides. Schlumberger determined that the geometry of their standard recessed area created these compression waves that cause interference that may adversely affect the performance of the perforating jets. These patents only mention that other types of recess geometries are available, some may have generally elliptical shapes, which is the standard industry elliptical scallop, and that such recess geometries may come at the expense of the body member **10** integrity as the recess may take up to much surface area of the body member **10** or remove too much body member **10** material. The present invention and the three preferred embodiments are all based on standard industry elliptical scallop for tubing guns and has nothing to do with compression waves.

[0034] One of the many embodiments of the Schlumberger patents is similar to the first embodiment of the present invention. Both patents depict and describe an emdodiment that does not have discrete bottom and side surfaces, that instead has a generally arcuate or curvilinear surface that extends around the periphery of the recess. It is further described as the arcuate surface of the recess is generally semi-hemispherical in shape and has a bottom surface portion that is continuous with a side surface portion along an arc. This is all various ways of describing the Sclumberger embodiment with some similarity to the radius cut **14** first embodiment of the present invention. So while these two recessed areas for the perforation have generally simillar shape, they are being utilized for totally different reasons. Schlumberger uses the shape as one of its many variations to possibly reduce the compression waves created from the Schlumberger prior art recessed area. The shape is being used in the first embodiment of the present invention

for the reasons stated of using the strength of the arch to allow a deeper cut removing more steel to be removed which absorbs less energy and deeper penetrating of the perforating jet into the rock formation.

[0035] The second embodiment of the present invention is depicted in a side view in FIG. **7** and in cross sectional views in FIG. **8** and FIG. **9**. The second embodiment, the radius with a flat scallop **18**, is similar to the first embodiment in that there is a radius cut with a curved surface **20**, but the second embodiment also has a flat portion **22** at the center of the scallop. The flat area **22** is longitudinal resulting in the elliptical shape. The flat area **22** is small relative to the rest of the radius with a flat scallop **18**. The arched portion of the radius with a flat scallop **18** provides the additional strength to maintain the structural integrity while removing more steel for a deeper penetration.

[0036] The third embodiment of the present invention is depicted in a side view in FIG. **10** and in cross sectional views in FIG. **11** and FIG. **12**. Part of the third embodiment appears as an industry standard elliptical scallop **26** with an additional longitudinal arching cut **28** and is referred to as the double cut scallop **24**. The tightly arched longitudinal arching cut **28** creates a flat area at the center of the scallop **30**. While described as the double cut scallop **24** because of its appearance, it is machined as one single cut. Such tooling to produce this economically has not been available until recently. The cross sectional views of the double cut scallop **24** show how significantly more steel is removed compared to the industry standard elliptical scallop **26**. This third embodiment again uses the strength of the arching cut to maintain structural integrity while removing more steel for deeper penetration.

[0037] Testing has been performed of various geometries including the three embodiments on various sizes of hollow steel carrier body members **10**. The smaller diameter

body members **10** have a smaller arch which affords more strength and so more steel can be removed. The larger diameter body members **10** have a larger arch which affords less strength and so less steel can be removed. The first embodiment, radius cut scallop **14**, is the most amount of steel to penetrate and affords the most strength. The second embodiment, radius with a flat scallop **18**, has less steel to penetrate and affords less strength than the first embodiment. The even larger flat portion of the third embodiment, double cut scallop **24**, affords less strength than either the first or second embodiments and is compensated for by the tighter inside arch. For these reasons, the first embodiment, radius cut scallop **14**, is for larger diameter body members **10** of more than four inches. The second embodiment, radius cut with a flat scallop **18**, is for medium diameter body members **10** of two and one half to four inches. The third embodiment, double cut scallop **24**, is for smaller diameter body members **10** of less than two and one half inches.

[0038] The design of the present invention and the three preferred embodiments are much better suited, over the prior art, to accomplish the objectives stated as well as those inherent therein. While the three preferred embodiments of the present invention have been described, numerous changes could be made by those skilled in the art which are encompassed within the spirit of the invention as described.